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THE ORIGIN OF THE EIGHT-YEAR GENERATING CYCLE

SUMMARY

The persistence of the eight-year generating cycle in England for one hundred and sixty years; the congruence of the eight-year crop cycles in England, France, and the United States; the persistence of the eight-year meteorological cycles, and their congruence in Europe and America; the congruence of the economic and meteorological cycles — these uniformities and agreements suggest that their cause must be sought in a cosmical cycle. The probable cause is the planet Venus in its eight-yearly periodic motion with respect to the Earth and the Sun.

GENERATING economic cycles are to be described as economic cycles that have their origin in non-economic causes and become the originating source of derived economic cycles. The theory of generating cycles embraces three fundamental inquiries: first, as to the existence of generating cycles, their length, amplitudes and phases; second, as to the ways in which the generating cycles work out their rhythmic effects in remote phases of economic life; and third, as to the cause of generating cycles. In other essays I have dealt with the first and second of these divisions. The present paper attempts to place the cause of the eight-year generating cycle.

I. Economic Cycles

If index numbers of the annual yield per acre of American crops are plotted for a considerable period, from 1882 to the present time, for example, the graph will be a composite of three types of changes — secular, cyclical, and random — which were long ago classified and described by Cournot. In a recent article in this Journal [1] I eliminated the secular changes in the yield per acre of the six leading crops in American agriculture, and then formed index numbers of their percentage deviations from the respective secular trends. The series of index numbers was then scrutinized with a view to finding evidence of a real, recurring cycle, and Figure 1

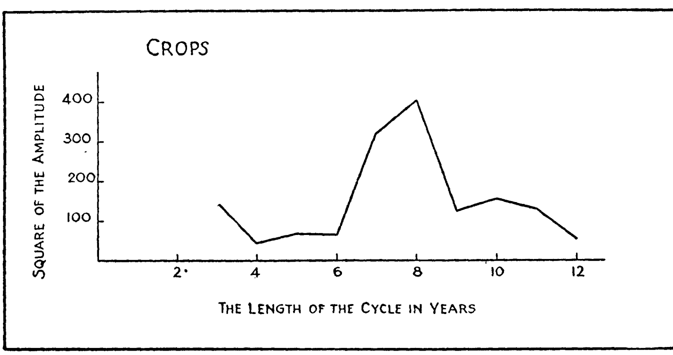

FIGURE 1. Periodograph of the yield per acre of American crops.

shows that of all possible cycles between three and twelve years in the index numbers of the yield per acre of the crops, the most probable length is in the neighborhood of eight years. If an eight-year cycle is fitted, by the method of least squares, to the index numbers of yield, the maxima of the repeated cycle fall, approximately, at 1882, 1890, 1898, 1906, 1914. In other

1. "Generating Cycles of Products and Prices," February, 1921.

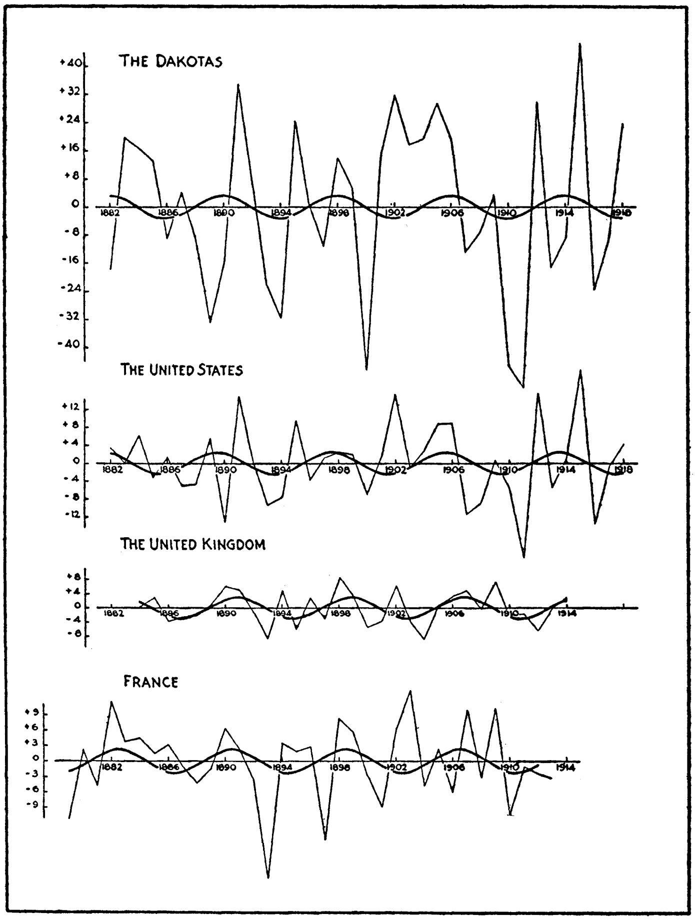

FIGURE 2. Cycles in the yield of wheat, oats, and barley in the Dakotas, the United States, the United Kingdom, and France.

The Dakotas: $y = 3.20 \sin (\frac{360°}{8}t + 93° \; 9')$, origin at 1882;
The United States: $y = 2.49 \sin (\frac{360°}{8}t + 111° \; 27')$, origin at 1882;
The United Kingdom: $y = 3.02 \sin (\frac{360°}{8}t + 142° \; 0')$, origin at 1884;
France: $y = 2.17 \sin (\frac{360°}{8}t + 292° \; 56')$, origin at 1879.

studies [2] referring to the Dakotas, the United States, the United Kingdom, and France, the eight-year cycles were isolated and were found to be practically synchronous in these countries. Figure 2 shows the graph descriptive of the eight-year cycles in the yield of wheat, oats, and barley.

With the existence of an international cycle in the yield of the crops firmly established, an obvious corollary suggested that according to the law of demand — in consequence of which the price tends to fall with an increase in the supply of the commodity — there should be a derived eight-year cycle in the prices of farm products. Accordingly, the law of demand for the six representative American crops was ascertained, and the derived cycle of prices of farm products was computed from the established eight-year cycles in the yield of the crops. The results are presented in Figure 3, together with a comparison between the actual index numbers of prices and the forecast indices of prices.[3]

After ascertaining that the prices of agricultural products do actually vary inversely with the yield in a definite, predictable way, it became possible to subject the theory of the existence of generating cycles of crops to a severe critical test. If the prices of agricultural commodities do vary inversely with the yield, and if there is a real cycle of eight years in the yield of the crops, then the record of prices throughout a long interval should reveal the existence of the eight-year generating cycle of crops. Moreover, if the generating cycle is a persistent, real cycle, then the cycle of yield per acre that is revealed indirectly by the record of prices

2. "Crop-Cycles in the United Kingdom and in the United States," Journal of the Royal Statistical Society, May, 1919; "Crop-Cycles in the United Kingdom and in France," ibid., May, 1920; "Forecasting the Crops of the Dakotas," Political Science Quarterly, June, 1920, particularly pp. 228, 229.

3. Figure 3 is taken from "Generating Cycles of Products and Prices," in this Journal, February, 1921, p. 227.

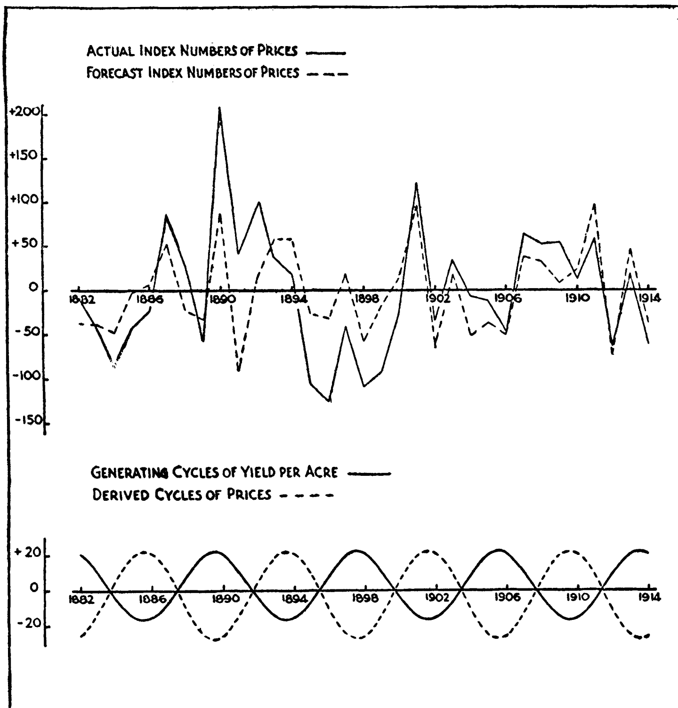

FIGURE 3.

Upper part: Actual index numbers of prices of the six representative crops and the index numbers of prices forecast from the index numbers of the yield per acre by means of the formula

$$y = -1.295x - .02.$$

Lower part: Generating cycles of the yield per acre of the crops,

$$y = 1.6 + 20.0 \sin (45°t + 109°), \text{ origin at } 1882;$$

Derived cycles of prices of the crops computed from the generating cycles of yield by means of the formula,

$$y = -1.295x - .02.$$

throughout a long interval should be the same as the cycle that is obtained directly from the more recent official estimates of the actual yield per acre. Figure 4 shows not only that the record of prices in England from 1760 to 1875 exhibits a clear-cut cycle of eight years in the yield per acre,[3a] but also that the cycle is

3a. Figure 4 is taken from "Generating Cycles Reflected in a Century of Prices," in this Journal, August, 1921, p. 520.

continuous with the eight-year cycle which is established directly from the official estimates of the crop yields since 1884.

The theory of the generating cycle also requires that the movement of general prices should follow the rhythmic changes in the yield of agricultural products. As nearly all foods are derived either directly or indirectly from the farms, and as eighty per cent of the raw materials of manufactures — according to the United States census of 1900 — are organic raw materials produced on the farms, the movement of general prices should reflect the rhythm in the yield of the crops. Here it became possible to subject the theory of the relation between the generating cycles of crops and the movement of general prices to a searching empirical test. Sauerbeck's index numbers of general prices, covering the interval of nearly a century between the Napoleonic wars and the Great War, were examined by means of Fourier analysis with a view to discovering real periodicities. The analysis showed that if there were a sequence of real cycles in the century of prices in England, the most probable length of the constituent cycle was approximately eight years. When this cycle of general prices was computed and plotted, its graph was found to be practically congruent with the graph of the yield of wheat which was determined indirectly from the record of wheat prices from 1760 to 1875, and practically congruent with the graph of the cycles in the yield of the crops which was determined directly from the official estimates of the annual yield of the crops since 1884. The graphs are given in Figure 4.

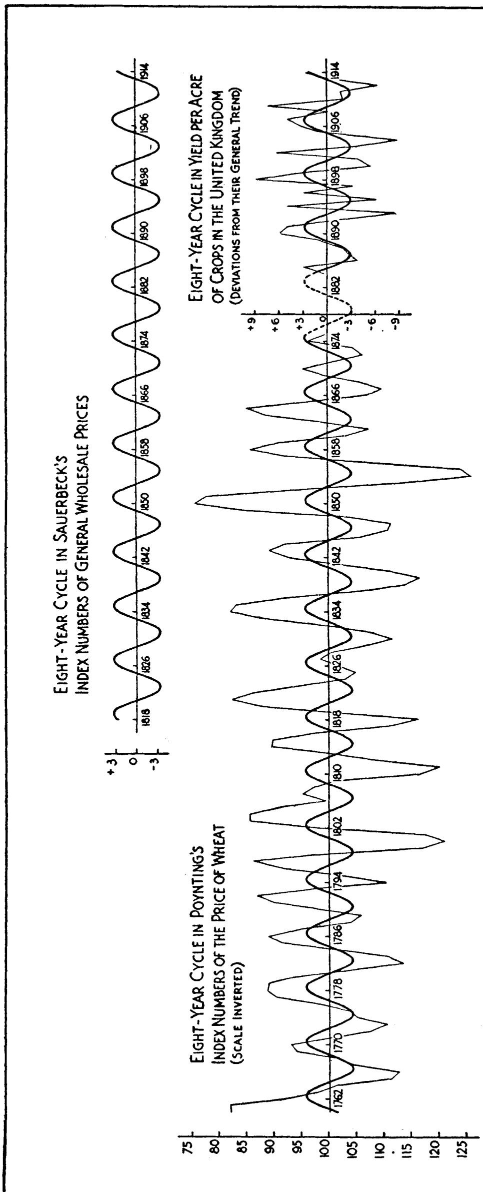

FIGURE 4. Generating cycles reflected in a century of prices.

Upper curve: $y = 3.5 \sin (\frac{360^\circ}{8}t + 51^\circ)$, origin at 1818. Derived from the 8.73 and 7.38 years Fourier constituents of Sauerbeck's index numbers.

Lower curves: Poynting's index numbers, $y = 100.2 + 4.4 \sin (\frac{360^\circ}{8}t + 248^\circ)$, origin at 1762;

Yield per acre of the crops, $y = 3.0 \sin (\frac{360^\circ}{8}t + 142^\circ)$, origin at 1884.

II. Meteorological Cycles

In 1919 the Carnegie Institution published *Climatic Cycles and Tree-Growth*, by A. E. Douglass. With the hope of throwing some light on the periodic activity of the sun, Professor Douglass, by training and profession an astronomer, undertook this laborious and valuable investigation of the variation in the size of the rings of trees, which, he assumed, was a consequence of meteorological changes having their origin in solar activity. He selected for his first studies yellow pines taken from the forests of northern Arizona. As there is, for the most part, a scant and variable rainfall throughout the state, Professor Douglass assumed as a working theory (1) that the growth of pines in that region depends largely upon the available water; (2) that the rings of the pines measure the growth of the trees; (3) that the rings form a measure of annual precipitation.

The rainfall of Arizona is extremely variable from station to station. "Storms come from the Pacific coast and rain occurs a day or so later than in southern California. Spring and autumn are the dry seasons, and the warmest time of the year is usually in June, just before the summer rains begin. The summer rains occur in July and August and often come in 'spells' that last a week or two, with thunderstorms in the afternoons or at night, followed by clear mornings. Unlike the winter storms, the summer rains are local and apt to be torrential in character, with heavy run-off." The San Francisco Peaks, ten miles north of Flagstaff, "illustrate how meteorological data may vary in rugged localities. The west slopes of these mountains are exposed to the westerly storms and have an immense snowfall. Springs abound, and all favorable localities are

taken up as ranches. East of the mountain, however, the land is dry and barren, and long distances intervene between watering places. . . . In a very rugged country like that about Prescott similar differences between east and west mountain slopes must constantly occur."

The longest meteorological record in the Arizona pine forest was begun at Whipple Barracks, near Prescott, in 1867, and then continued at Prescott, which has

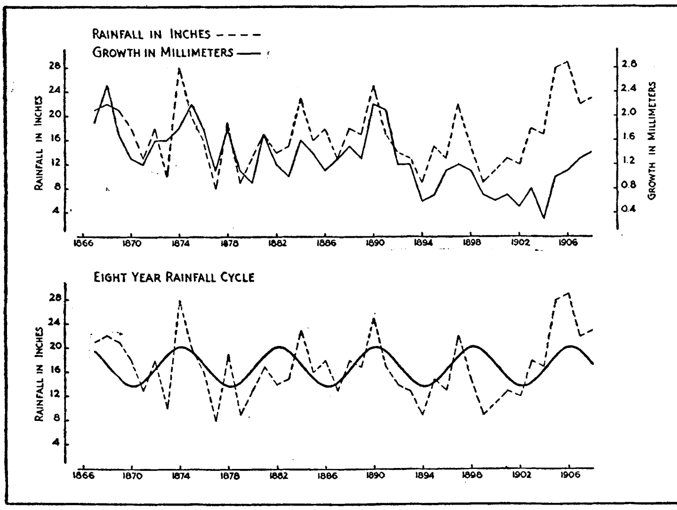

FIGURE 5. Cycles in the rainfall and in the growth of pines near Prescott, Arizona. Equation to the rainfall cycle, $y = 16.9 + 3.2 \sin (\frac{360°}{8}t + 127° 12')$, origin at 1867.

an elevation of about 5200 feet. With the variability of rainfall from station to station which we have just noted, and with the change of the meteorological observation from Whipple Barracks to Prescott, one would scarcely expect any normality to be revealed in this particular rainfall record. An examination of Figure 5 is, nevertheless, surprisingly suggestive. The top graph [4] shows the relation between the annual rainfall and the

4. The top graph is taken from Professor Douglass' work, p. 29.

growth of pines near Prescott. The growth seems to show a secular trend downwards and for that reason, in seeking the degree of relation between the annual rainfall and the annual growth, I have computed the correlation between their first differences. The measure of this relation is $r = .56$, which shows that there is an unmistakable relation between the rainfall and the growth of pines in this region.

Is the rainfall itself subject to law? In the lower part of Figure 5 an eight-year cycle is fitted to the annual rainfall data, and we find that the maxima occur at 1866, 1874, 1882, 1890, 1898, 1906 — which makes the Prescott rainfall, during this interval, synchronous with the crop cycles in the United States, in the United Kingdom, and in France. Gratifying as this result is, I should not attach importance to it — because of the meteorological record being made up of observations at two different stations in a country in which the rainfall is notoriously variable from station to station — but for its relation to what is about to be described.

Flagstaff, in Arizona, is about 67 miles north of Prescott. From the magnificent pine forests about Flagstaff Professor Douglass was able to obtain cuttings from trees which supplied him with a continuous history of rings for 500 years. Referring to these Flagstaff pines, Professor Douglass makes these statements as to the cyclical variations in their growth: "The interval from 1830 to the present time divides . . . fairly well in (a period) of 7.3 years" (p. 108). As to the whole record of 500 years, he says, "a 7-year period is also frequently observed" (p. 101). In Table 8 (p. 108) Professor Douglass indicates that this cycle of approximately 7.3 years has been continuous since 1817. By an odd coincidence Sauerbeck's index numbers of general prices in England begin just one year later, in 1818.

In the analysis of the Sauerbeck numbers we found[4a] that the eight-year cycle was the mean of two cycles, one of about 8.7 and the other of about 7.38 years. In Figure 6 the smooth graph records the 7.38-year cycle in Sauerbeck's index numbers, and the dashed graph,[5] the

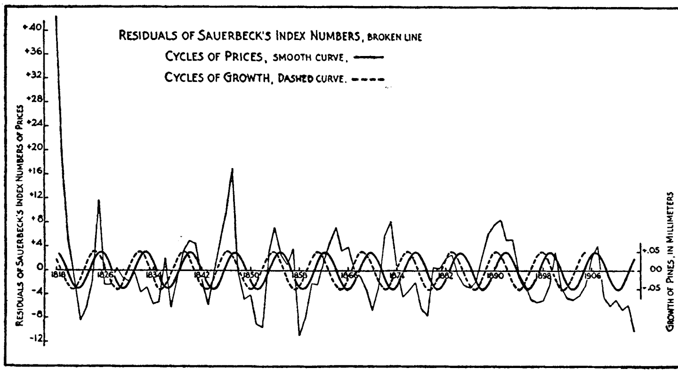

FIGURE 6. Cycles in the residuals of Sauerbeck's index numbers of general wholesale prices in England and in the growth of pines near Flagstaff, Arizona.
Equation to the cycle of prices, —— : $y = 3.1 \sin \left(\frac{360^\circ}{7.38} t + 92^\circ\right)$, origin at 1818;
Equation to the cycle of growth, ····· : $y = .05 \sin \left(\frac{360^\circ}{7.33} t + 137^\circ\, 57'\right)$, origin at 1818.

Douglass 7.3-year cycle in the Arizona pines. The two graphs, considering the errors in the estimated lengths of the cycles, are practically congruent, and from 1867 to 1910 the Douglass 7.3-year cycles in tree growth at Flagstaff run well with the eight-year cycles in the rainfall at Prescott.

The close relation between meteorological cycles and crop cycles is informingly illustrated in the crops of the spring-wheat area in the United States. In 1916, among the states of the United States, North Dakota ranked first in the production of spring wheat,

4a. "Generating Cycles Reflected in a Century of Prices," in this Journal, August, 1921.

5. The data to which the cycle was fitted covered the 88 years from 1818 to 1905 and were taken from Professor Douglass' work, p. 113.

second in the production of barley, and seventh in the production of oats; and to these three crops, in 1918, seventy per cent of its crop area was devoted. The semi-arid region of the United States begins to the west of the one-hundredth meridian, and this meridian divides nearly in two the state of North Dakota. The average precipitation does not greatly exceed the minimum that is essential for vegetation, and, consequently, we find a close correlation between the crop yield and the rainfall of the critical months, which are May and June. The correlation coefficients[6] between the rainfall of May and June and the yield of the crops are, for wheat, $r = .66$; for oats, $r = .79$; and for barley, $r = .73$.

With this close relation between rainfall and crop yields established for this very important, semi-arid agricultural region, one is again led to inquire whether the rainfall itself is not subject to law.[7] The rainfall records of North Dakota and South Dakota, for May and June, from 1882 to 1918 were searched for evidence of periodicity between the limits of three and twelve years, and the result indicated that, if there is a real cycle of rainfall for May and June in these two representative states its most probable value is in the neighborhood of eight years. When an eight-year cycle is fitted to the rainfall data, the maxima occur, approximately, at 1882, 1890, 1898, 1906, 1914, and are practically synchronous with the dates of the maxima of rainfall of Prescott, Arizona, the growth of pines in Arizona, and the maxima of the international crop cycles in the United States, in the United Kingdom, and in France. The graph of the Dakota rainfall is given in Figure 7.

6. "Forecasting the Crops of the Dakotas," Political Science Quarterly, June, 1920, p. 219.

7. This question I have treated in a paper on "Forecasting the Crops of the Dakotas," Political Science Quarterly, June, 1920.

Starting from the hypothesis that American economic activity is largely dependent in its ebb and flow upon the prosperity of the agricultural Middle West, I sought, in an early study [8] of meteorological cycles, to discover

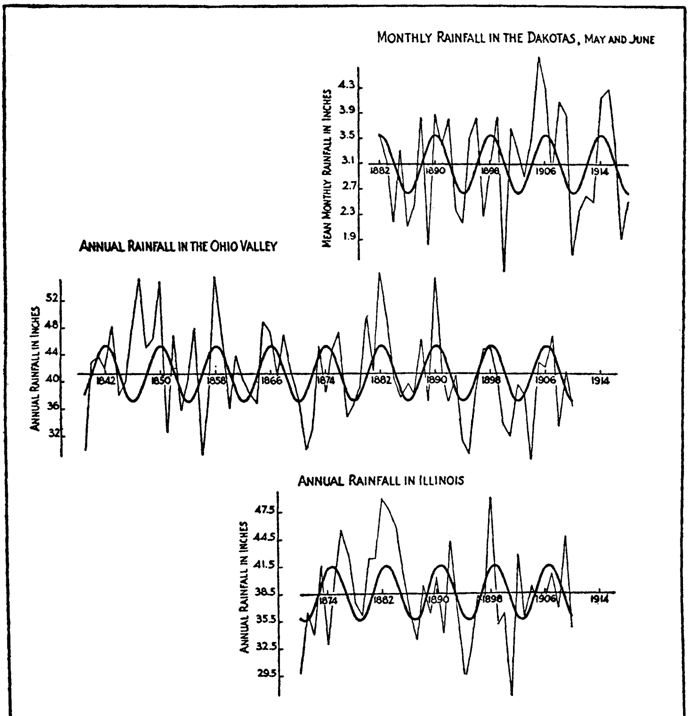

FIGURE 7. Cycles in the rainfall of the Dakotas, of the Ohio Valley, and of Illinois.
Dakota cycle: $y = 3.09 + 0.45 \sin\left(\frac{360°}{8}t + 84° 39'\right)$, origin at 1882;
Ohio cycle: $y = 41.2 + 4.13 \sin\left(\frac{360°}{8}t + 310° 41'\right)$, origin at 1839;
Illinois cycle: $y = 38.5 + 3.05 \sin\left(\frac{360°}{8}t + 241° 52'\right)$, origin at 1870

a periodicity in the rainfall of the Mississippi Valley. As the meteorological records were much longer for the Ohio Valley than for the states further west, the rainfall of the Ohio Valley was made the basis of the first examination. The method employed was a test of the

8. Economic Cycles: Their Law and Cause, 1914.

possible presence of cycles between the limits of three and thirty-three years, and the evidence was unmistakable. If there is a real cycle of rainfall in the Ohio Valley its most probable length is about eight years and its maxima are approximately synchronous with the maxima of the May and June rainfall of the Dakotas, the annual rainfall of Prescott, Arizona, the growth of pines in Arizona, and the international crop cycles to which we have so frequently referred. The graph is given in Figure 7.

At the time of the publication of the essay *Economic Cycles*, 1914, Illinois was regarded as our leading cereal-producing state, ranking first in the production of corn and second in the production of oats. Rainfall records for many stations in that state were available for a period of 41 years, from 1870 to 1910. The correlation between the rainfall in the Ohio Valley and the rainfall of Illinois was $r = .60$, and the eight-year cycle in the Ohio Valley rainfall was repeated in an eight-year cycle in the rainfall of Illinois. The graph is likewise given in Figure 7.

In October, 1920, H. W. Clough of the United States Weather Bureau published in the *Monthly Weather Review* an article on "An Approximate Seven-Year Period in Terrestrial Weather, with Solar Correlation." From this paper I make use of two facts: the first refers to atmospheric pressure at Toronto, in Canada, and at St. Louis, in the United States. In Mr. Clough's paper a graph is given of atmospheric pressure at Toronto from about 1843 to 1911, and a similar graph is given for the pressure at St. Louis from about 1874 to about 1917. An inspection of these shows (1) that for the interval covered by the two graphs, they are approxi-

mately congruent; (2) that the maxima occur, approximately at 1850, 1858, 1866, 1874, 1882, 1890, 1898, 1914, and are therefore synchronous with the economic and meteorological cycles already examined.

The other fact that I take from Mr. Clough's paper refers to atmospheric pressure in Europe. "Mauer (*Archives des Sci. Phys. Nat.*, Geneva, May, 1918) called attention to a well-marked periodicity of seven to eight years in the winter pressure in Central Europe, with maxima as follows: 1818–19, 1827–28, 1835–36, 1843–44, 1850–51, 1857–58, 1865–66, 1873–74, 1881–82, 1889–90, 1897–98, 1904–05, 1912–13."

If now the dates of the maxima in Mauer's European pressures are compared with Clough's in America, it will be seen (1) that they are approximately synchronous; (2) that the common interval between the maxima is about eight years; (3) that they are approximately synchronous with the maxima of the crop cycles in the United States, in the United Kingdom, and in France; (4) that they are approximately synchronous with the cycles in Sauerbeck's index numbers from 1818 to 1914.

The next evidence of meteorological cycles is found in an official publication by the United States Weather Bureau. In 1901 the United States took "the lead in reducing its barometric observations to a standard system."[9] The work was conducted by Professor F. H. Bigelow and included "a reëxamination of the various elevations, the local and instrumental errors, the reduction of the station pressures to a homogeneous system, and the preparation of normal tables and charts of pressure, temperature, and vapor pressure at sea level and at the 3,500 foot and 10,000 foot planes."[10] This

9. Prefatory note in vol. ii of Report of the Chief of the Weather Bureau, 1900, 1901.
10. Report of the Chief of the Weather Bureau, 1900–01, vol. i, p. 12.

monumental work bears the title *Report on the Barometry of the United States, Canada, and the West Indies*, and constitutes volume II of the *Report of the Chief of the United States Weather Bureau, 1900, 1901*.

After the completion of this Report with the reduced and standardized material, it became possible for the first time to combine the many thousands of observations that had been made in the United States since the beginning, in about 1870, of the systematic work of official weather observation. The tremendous importance of this great increase in the utilizable meteorological observations is shown in what is, I think, the most pregnant conclusion of Professor Bigelow's Report. I shall quote that conclusion at length and invite particular attention to a few sentences which I have put in italics. The table referred to in the quotation is one in which the final mean pressures for the whole of the United States and for the several constituent large sections are presented. In detail, the barometric pressure series upon which the generalization was based were obtained from the following sections: North Atlantic, South Atlantic, Lake Region, Pacific, West Gulf, North Plateau, South Plateau, and from the records of these regions all combined into a general mean. The pregnant quotation is now given:

We are at once struck by the remarkable fact, which constitutes an *important discovery in barometric science*, that the secular variations of the barometer from year to year are by no means accidental but a phenomenon of definite proportions. In looking over the tables it is seen that for certain years the barometric reading is persistently lower than the average of the series, and for certain other years it remains higher than the average. This fact is indicated, generally, by each station in the group, most conspicuously for the year 1878. The residuals of that year are persistently minus, about −0.050 inch *for each station in every group for the entire United States;* for the year 1883 they are as persistently plus, about +0.020 inch. This constitutes a range of 0.070 inch, and when we consider that the

annual range in the barometer, due to the change of the sun in latitude from +23° to −23°, causing the change in the seasons, the difference between winter and summer, is shown by Table 54 to be about 0.100 inch, we conclude that *we are dealing with a phenomenon which at times is seven-tenths of the annual departure in its intensity.* The fact is that the barometric pressure is sometimes maintained higher than the average throughout the entire year over a large continental area in middle latitudes, and that it often equals at least half as much as the influences of the sun's action on the atmosphere by departing 23 degrees in latitude from the equator; in other years the pressure is kept lower than the average by a similar amount. *The years of maximum pressure are 1874–75, 1882–3, 1890, 1896–7, with an interval of about 8 years between them successively; the years of minimum pressure are 1878, 1884–5, 1893, also having an interval of about 8 years. . . .*"

In seeking for the causes of this phenomenon, I confess that it has been difficult to assign one which is satisfactory. It cannot be a wave motion because the duration of each wave is too long to admit of anything resembling propagation. One suspects that there may be a tilting of the atmosphere from one continent to another, or from one hemisphere to the other, but when we consider the rapid motion of the upper strata of the atmosphere, it does not appear how it can so far deviate from its usual paths as to leave an entire continent lower or higher than the average for so long a time. *One may also suspect purely cosmical causes* due to the variable solar output; indeed, these barometric variations do closely follow the variations in the sunspot frequency and the other products of the sun's variable activity. From 1873 to 1890 there is a remarkable agreement between these two classes of phenomena, *but if the pressure period is 8 years and the sunspot period 11 years that connection cannot be complete in its nature.* It is evident that we shall be obliged to prosecute this study yet further by constructing similar barometric tables for other countries, in each hemisphere, and also that it will be well to include in our research some account of the temperature, the vapor tension, and the magnetic and electric fields of the atmosphere before attempting any further remarks on the subject. . . .

Finally, it is evident that for the United States we can now correlate the years which have similar secular variations, as 1878, 1885, and 1893, and study them climatologically to see if there are any marked and prevailing features which characterize them. *It is clear that this discussion opens to us for the first time the prospect of a scientific basis for seasonal forecasts,* certainly so if it should prove to be the case that the maximum-pressure years differ distinctly from the minimum-pressure years in their seasonal character, for in

the event of our happening on a maximum year we could then predict the feature due to a falling barometer, or, if we are in a minimum year, to a rising barometer, at least for one or two years ahead.[11]

Upon the preceding passages I make these notes:

(1) As far back as 1901 the United States Weather Bureau isolated a cycle in the barometric pressure of the United States;

(2) That cycle was an eight-year cycle which was synchronous with the cycles in economics and meteorology to which constant reference has been made in this essay;

(3) Professor Bigelow regarded the isolation of the cycle as "an important discovery in barometric science," the discussion of which "opens to us for the first time the prospect of a scientific basis for seasonal forecasts";

(4) Professor Bigelow suspected a cosmical cause of the phenomenon, but known solar periodicities failed to satisfy the conditions: "if the pressure period is 8 years and the sun-spot period is 11 years that connection cannot be complete in its nature."

What is the cosmical cause of the eight-year cycle?

III. The Cause of the Eight-Year Generating Cycle

Is there a cosmical cycle of approximately eight years in length, the effects of which upon the Earth might account for the observed meteorological cycles? Let us divide this question into two and ask (1) is there a cosmical cycle of eight years in length which is synchronous with the observed meteorological cycles? (2) is there reason for believing that the cosmical cycle

11. Report of the Chief of the Weather Bureau, 1900, 1901, vol. ii, pp. 1004, 1005.

is accompanied with a synchronously varying force that could produce the observed meteorological cycles?

The first question may be answered definitely and positively: there is a cosmical cycle of about eight years that is synchronous with the economic and meteorological cycles the existence of which has already been established.

Perhaps the best way to approach its description is to consider these facts: the maximum visibility of Venus is produced by its greatest phase, its greatest elongation from the sun, and the clearness of our atmosphere, and that maximum tends to recur at intervals of eight years. "Vénus passe tous les huit ans par ses périodes de plus grand éclat (1889–1897–1905–1913). Elle est alors si brillante qu'elle porte ombre comme un petit clair de lune, et il est facile de s'en assurer soit en se plaçant dans une pièce obscure, soit en marchant devant un mur à la campagne. On peut la distinguer en plein jour, à l'œil nu, non seulement avant le coucher du soleil, mais à midi même, lorsque l'on sait où elle est. Aucune étoile ni aucune planète n'atteint un éclat comparable à celui-là." [12] Here is an eight-year cycle in which the dates of maxima are a little in advance of our economic and meteorological cycle. It is not the cycle that we want, but it is closely related to the one for which we are in search.

Before passing to a detailed consideration of the Venus cycle a prejudice must be noted and, if possible, removed. In suggesting that the variability in the brilliance of Venus may have some possible relation to terrestrial affairs one is reminded at once of the disdainful attitude of Laplace: "Vénus surpasse en clarté les autres planètes et les étoiles; elle est quelquefois si brillante, qu'on la voit en plein jour, à la vue

12. Camille Flammarion, Rêves étoilés, pp. 132, 133.

simple. Ce phénomène qui revient assez souvent, ne manque jamais d'exciter une vive surprise; et le vulgaire, dans sa crédule ignorance, le suppose toujours lié aux événements contemporains les plus remarquables."[13] Now with regard to this remark, the substance of which is repeated by others in pamphlets and treatises, these comments should be made:

(1) Laplace's scorn was directed towards the prognosticators who encouraged the belief that particular, isolated events were predictable from the aspect of Venus.

(2) Until many years after the death of Laplace, economic and meteorological observations had not been carried sufficiently far to admit of the isolation of long-time cycles showing mean results which could be associated with cosmical variations.

(3) Many physicists and astronomers of unquestioned sanity and proven ability have attempted to discover the effect of Venus upon the position and frequency of sunspots. If that is not a visionary inquiry when Venus is nearly three times further from the Sun than it is from the Earth, the consideration of the possible effects of that planet upon the weather of the Earth should not be regarded as a preposterous undertaking.

Returning now to the question of the periodicity in the motion of Venus with respect to the Earth let us first recall that the relative distances of the Earth and Venus from the Sun are as 1000 to 723; that the orbits of both planets are nearly circular; and that in size, Venus of all the planets most nearly approaches the Earth, its diameter being 7630 miles as compared with the 7918 miles of the Earth.

Let Figure 8 represent the orbits of Venus and the

13. Laplace, Exposition du système du monde, Livre premier, chap. v.

Earth, the orbits being assumed, for the sake of simplicity, to be circles. At this stage no account is taken of the inclination of the plane of the orbit of Venus, which will be considered later on. The following simple

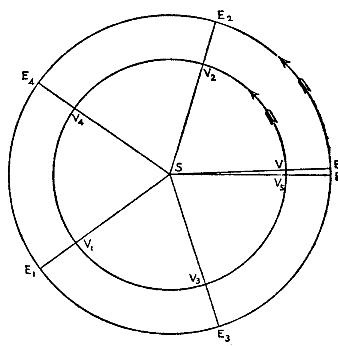

FIGURE 8. Illustration of the conjunctions of the Earth and Venus.

description of when and where the two planets are in conjunction is given by R. A. Proctor in his *Transits of Venus:*

> Imagine that a straight pointer from the Sun to Venus, extending to the Earth's orbit, like the line SVE, is carried round S as a central pivot by the motion of the planet Venus. Then whenever this pointer comes up to the Earth, the three bodies — Sun, Earth, and Venus — are in conjunction. Now, Venus travels with a mean motion of 96′ 7″.8 per day around the Sun (completing a revolution in 224.701 days), while the Earth travels with a mean motion of 59′ 8″.3 (completing a revolution in 365.257 days); so that in each mean solar day Venus gains, on the average, 36′ 59″.5 upon the Earth. This is the rate at which our imaginary pointer, starting from a position such as SVE, sweeps onwards from the advancing Earth, so as to again reach the Earth by overtaking it, just as the minute-hand of a clock, after being in conjunction with the hour-hand, passes on towards its next conjunction, with the *excess* of its motion over the hour-hand. We have only, then, to ask how long it will take the pointer, with its mean daily gain of 36′ 59″.5, to gain one complete circuit, to have the interval in time between successive conjunctions of the Earth and Venus—in other words, there will be just as many days in this interval as the number of times 36′ 59″.5 is

contained in 360°, or, reducing both to seconds, as 2219.5 is contained in 1,296,000. The division . . . gives us 583.9 days.

Our Venus-carried pointer thus takes 583.9 days in overtaking the Earth. This is more than a year by about 218.6 days, in which period, with her mean motion of 59′ 8″.3 per day, the Earth travels round nearly $215\frac{1}{2}$ degrees. Now, 216 degrees would be $\frac{3}{5}$ of a complete circuit. We see, then, that the next conjunction-line must be set almost exactly $\frac{3}{5}$ of the way round from SVE, or in the position SV_1E_1; the next will have the position SV_2E_2; the third will have the position SV_3E_3; the fourth, the position SV_4E_4; and the fifth will be close up to SVE, in the position SV_5E_5, about $2\frac{1}{2}$ degrees behind SVE.

Since the interval between each conjunction is about a year and three-fifths, the whole time occupied before the position SV_5E_5 is reached by the conjunction-line will be five times $1\frac{3}{5}$ years, or 8

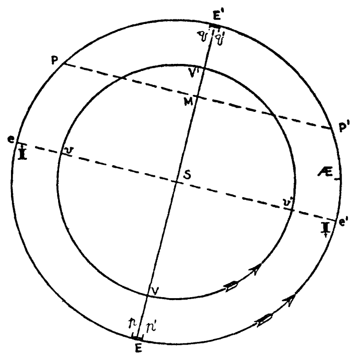

FIGURE 9. The transit regions (pp′ and qq′) in the Earth's orbit.

years, less the short interval corresponding to the Earth's motion over the arc E_5E. We see, then, how it comes to pass that an interval of eight years brings round nearly the same circumstances as at the beginning of the interval, and why, therefore, when a transit has occurred, another may occur eight years later. . . .

And now let us consider the effect of the inclination of the orbit of Venus to that of the Earth, still, for the sake of simplicity, leaving out of account the slight eccentricity of the orbits.

If EE′, VV′ (Figure 9), represent the two orbits,[14] and Æ be the place of the Earth at the autumnal equinox, then the line EE′ represents the intersection of the two orbit-planes; and if, as before, we regard the plane of the paper as containing the orbit EE′,

14. In the description of Figure 9 I have altered slightly Proctor's lettering so as to correspond with the use I shall make of the reasoning later on. Proctor starts with the transit of 1631 while I begin with that of 1761.

then the part V′vV of the path of Venus is to be regarded as slightly above, the part Vv′V′ as slightly below, the plane of the paper. Accordingly the end of the pointer which we have supposed Venus to carry round the Sun, passes above the semi-circle E′eE and below the semi-circle Ee′E′. And supposing this pointer to be of the length SE, so that its end appreciably travels round Ee′E′e (except for the displacement below and above the plane of this orbit), it is easy to calculate how much above or below the level Ee′E′e the end of the pointer runs. When in the direction SE or SE′, of course the Venus-carried pointer has its extremity on the Earth's path; when in direction Sve or Sv′e′, at right angles to EE′, the end of the pointer is at its farthest from the plane Ee′E′e. The inclination of the orbit of Venus being about 3° 23½′, and the distance Se (the Earth's distance from the Sun) being about 91,430,000 miles,[15] it is easily calculated that the extremity of the pointer passes above *e* and below *e′* at a distance of about 5,409,000 miles. At any other point, as P or P′, the end is above or below by an amount less than 5,409,000 miles in the same degree that PM or P′M is less than eS, or e′S (PMP′ being drawn square to EE′).

By means of this theorem Proctor computes that the length of the transit regions pp′, qq′ is about 3° 28′.

Figure 10 will facilitate the discussion of the eight-year cycle of Venus in its relation to the Earth and the Sun. In 1761 and in 1769 there were June transits of Venus and in 1874 and 1882 there were December transits. Let us assume that at the 1761 transit the Earth and Venus stood in their orbits at the points V and E. Then according to the reasoning which has just been traversed the next inferior conjunctions of Venus and the Earth were at E_1V_1, E_2V_2, E_3V_3, E_4V_4, E_5V_5. The conjunction at E_5V_5 was just 2° 22′ behind the point at which Venus and the Earth stood eight years before, and as E_5 fell within the transit region there was a June transit in 1769. Now just as the fifth conjunction E_5 was 2° 22′ behind E, so the sixth conjunction occurred 2° 22′ behind E_1; the seventh, 2° 22′ behind

15. Proctor's work, Transits of Venus, was published in 1875. Since that date the mean distance of the Earth from the Sun has been ascertained to be about 92,900,000 miles. The difference between Proctor's figures and the real distance affects the accuracy of his subsequent calculations.

E_2; the eighth, 2° 22′ behind E_3; the ninth, 2° 22′ behind E_4; and the tenth, 2° 22′ behind E_5. In case of all five of the conjunction regions, there were inferior conjunctions 2° 22′ behind the points of conjunction

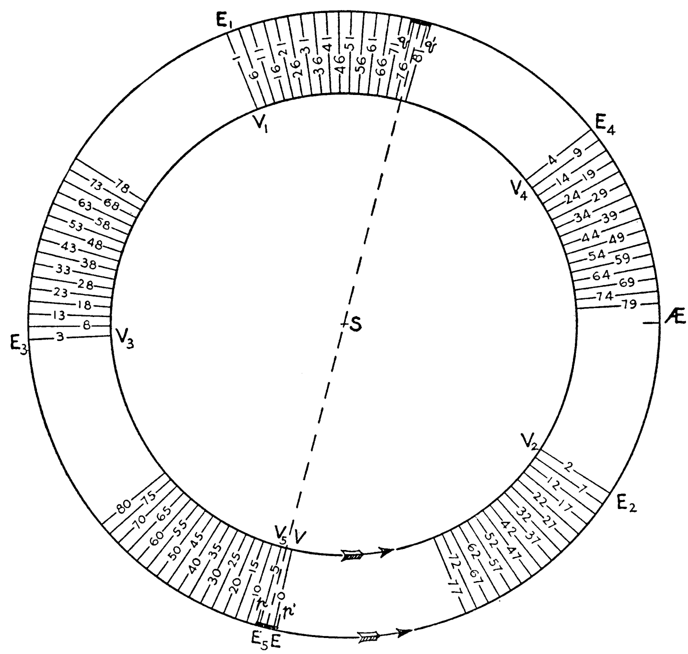

FIGURE 10. The regression of the conjunction lines of Venus and the Earth.

which occurred eight years previously. The sequence is followed out in Figure 10 to the 81st conjunction.

If now we keep the eye upon the two transit regions pp′, qq′, we observe that the recession of the conjunction lines at the rate of 2° 22′ in eight years caused the conjunctions in the region VE to recede from the transit region pp′, and those in the region V_1E_1 to approach the transit region qq′. The distance of E_1 from E is about 215½° and the distance of the transit region qq′ from the transit region pp′ is 180°. As the transit region is

itself about 3° 28′, it is obvious that the distance of E_1 from the transit region is about 34°; and as the conjunctions in the region E_1 approach the transit region qq′ at the rate of 2° 22′ every eight years while the conjunctions in the region pp′ recede at the rate of 2° 22′ every eight years, it is clear that a conjunction must occur within 17° of either the pp′ or the qq′ transit region every eight years. It is this eight-yearly conjunction in the neighborhood of the transit regions which is synchronous with the eight-yearly terrestrial phenomena that we have already described. This eight-yearly cycle is the Venus cycle for which we have been in search.

Up to this point no account has been taken of the small eccentricities in the orbits of the Earth and Venus and of the unequal motions of the planets in the different parts of their orbits. The consequences of these facts are so well known that they have been calculated,[16] and it is sufficient for our purpose to observe that the eight-year sequence in the transit regions — the Venus cycle — still persists when the eccentricities of the orbits and the varying motions of the planets are taken into consideration.

We see, therefore, that in 1761 and again in 1769 the Earth, Venus and the Sun were in a straight line in the transit region pp′; they were again in a straight line in 1874 and 1882 in the transit region qq′. Between the limiting dates 1761 and 1882, at intervals of approximately eight years, the Earth, Venus, and the Sun, in this sequence, made their nearest approach to being in a straight line. After 1882 until the date of the next transit in 2004, the Earth, Venus and the Sun will make this maximum approach to a straight line, in this sequence, at intervals of approximately eight years.

16. Proctor, Transits of Venus, pp. 111–118.

Now the longest record we have of economic cycles is given in Figure 4, which is the record of the crops in England. That invaluable sequence runs from 1760 to 1914. The maxima of the crop cycles occurred at 1762 and at intervals of eight years thereafter. The Venus cycle had maxima in June 1761 and approximately eight years thereafter, so that at intervals of eight years before and after the dates of the last transits in December 1874 and 1882, the maxima of the economic, meteorological, and Venus cycles were congruent.

We come now to the second part of our question: is there reason for believing that the Venus cycle is accompanied with a synchronously varying force which could produce the observed meteorological cycles? Here our point of departure is a comparatively recent discovery of great importance relating to the period of rotation of Venus upon its axis.

From the observations of some faint markings supposedly on the surface of Venus, Domenico Cassini of Bologna in 1666–67 inferred that the period of rotation was about twenty-three hours. J. J. Cassini, in 1740, gave a more exact estimate of twenty-three hours and twenty minutes. Schroeter, in 1789, fixed the period at twenty-three hours and twenty-one minutes, and De Vico, in 1839–41, carried the spurious accuracy to twenty-three hours, twenty-one minutes, and twenty-two seconds. So the matter remained until 1890, when Schiaparelli announced his surprising discovery.

Schiaparelli made the innovation of conducting his observations by day, as near to noon as possible, when Venus would be highest and its own glare reduced by the brilliant midday sky. From a long series of careful observations he concluded that the period of rotation of Venus upon its axis could be nothing like twenty-

four hours, but must lie between six and nine months and very probably agreed exactly with its period of revolution around the Sun, which is, approximately, 225 days.

In 1896 the question was made the subject of research by Percival Lowell with the assistance of an accomplished staff, at his observatory in the clear air of Flagstaff, Arizona. The markings noted by Schiaparelli upon which he based his conclusions as to the long period of rotation were verified at the Lowell Observatory, and in addition new markings were discovered and photographed. "By watching them assiduously it was possible to note that no change in position occurred in them, first through an interval of five hours, then through one of days, then of weeks. Care was taken to guard against illusion. It thus became evident that they bore always the same relation to the illuminated portion of the disk. This illuminated part, then, never changed. In other words, the planet turned always the same face to the Sun. The fact lay beyond a doubt, though of course not beyond a doubter." [17] Thirteen years after these first discoveries Professor Lowell repeated, in 1909, the account of his early work and then said "the years that have passed since these observations were made have brought corroboration of them. Several observers at Flagstaff have seen and drawn them and added discoveries of their own." [18]

The conclusion that the period of rotation of Venus upon its axis is the same as its period of revolution around the Sun was reached by Schiaparelli and Lowell from telescopic observations. There was, of course, the possibility, tho not the probability, that both observers had been misled by visual errors. But no such

17. Percival Lowell, The Evolution of Worlds, pp. 77–79.

18. Ibid., p. 79.

deception could occur with the spectroscope, and to make sure of his ground Lowell installed at his observatory a spectroscopic equipment. The investigator was Dr. Slipher, the present Director of the Lowell Observatory. The accuracy with which Dr. Slipher could determine the rotation period of a planet by means of spectrograms was tested by his spectroscopic approximation of the well known periods of rotation of Mars and Jupiter. The rotation period of Mars is known to be $24^h\ 37^m\ 23^s.66$. Dr. Slipher determined its period from spectrograms within an hour of the true time. The rotation period of Jupiter is $9^h\ 50^m.4$. Dr. Slipher found the rotation period from spectrograms to be $9^h\ 50^m$, or within a minute of the exact time. When in an exactly similar manner, he made his observation of Venus, the spectrograms showed that the rotation period must exceed three months, which meant that so slow a rotation as three months was beyond the power of Dr. Slipher's spectroscope to disclose.[19]

Lowell regarded Dr. Slipher's spectrogram report as confirmatory of Schiaparelli's conclusion and his own that Venus rotates on its axis in the same time that it revolves around the Sun, turning always the same side to the source of light and heat.

The bearing of this discovery upon the theory of the effect of Venus upon terrestrial meteorological cycles we shall approach by considering the following quotation from Lowell: "That Venus turns on her axis in the same time that she revolves about the Sun, in consequence of which she turns always the same face to him, must cause a state of things of which we can form but faint conception, from any earthly analogy. One face baked for countless aeons, and still baking, backed by one chilled by everlasting night, while both are still

19. Lowell, The Evolution of Worlds, pp. 83–89.

surrounded by air, must produce indraughts from the cold to the hot side of tremendous power. A funnel-like rise must take place in the centre of the illuminated hemisphere, and the partial vacuum thus formed would be filled by air drawn from its periphery which, in its turn, would draw from the regions of the night side. Such winds would sweep the surface as they entered, becoming less superficial as they advanced, and the marks of their inrush might well be discernible even at the distance we are off." [20]

The last part of this quotation is perhaps hyperbole. I am very far from wishing to suggest that the winds of Venus may be directly responsible for the periodicity in terrestrial weather. Our question is this: is there reason for believing that the Venus cycle is accompanied with a synchronously varying force which could produce the terrestrial meteorological cycles? The consequence of the long rotation period of Venus with the one face always turned towards the Sun is that the planet is in a constant state of violent meteorological commotion on a vast scale; and this planet, which is about the size of the Earth, thrusts itself at intervals of eight years almost exactly in the direct path of radiation from the Sun to the Earth. Is it not probable that the storm-racked planet creates a disturbance in the interplanetary medium which affects the Sun's radiation on its way to the Earth? If that is the case, then the cause of the eight-year generating cycle is the planet Venus in its eight-yearly periodic motion with respect to the Earth and the Sun.

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20. The Evolution of Worlds, pp. 80–82.